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Research Methods to Develop Measures of Effectiveness of the United States Coast Guard's Vessel Inspection and Boarding Program

EXECUTIVE SUMMARY - VOLUME I

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NOTICE

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16. Abstract

This report describes a methodology for determining the effectiveness of the U.S. Coast Guard Marine Inspection and Boarding Program for deep draft vessels. Measures of Effectiveness (MOEs) were developed at the overall program-wide, major activity, and sub-activity levels.

Econometric analysis was performed on the relationship between the number of personnel and pollution casualties and the resource hours expended by the Inspection and Boarding programs. The estimates provide MOEs by 1) quantifying the decrease in expected number of casualties, and 2) quantifying the increase in the duration in days to a casualty that results from an increase in resource hours. A second methodology called Risk Based Ranking (RBR) was used to enumerate the contribution of factors targeted by sub-activities as being key contributers to the occurrence of casualties.

For U.S. vessels the results indicate that resources expended are effective in reducing expected number of deaths, injuries, and pollution incidents. For foreign vessels the results are not robust and do not allow clear inferences. The RBR showed that the dominant contributors to maritime risk are linked to Drills/Human Factors, Steering/Navigation, and Cargo/Pollution Control sub-activity intervention strategies. The order of these factors varies by vessel service and country of registry.

A prototype decision support system was developed that displays the econometric models graphically. This report is issued in four separate volumes: Volume I - Executive Summary; Volume II - Main Report; Volume III - Decision Support for Utilizing Measures of Effectiveness; Volume IV - Appendices.

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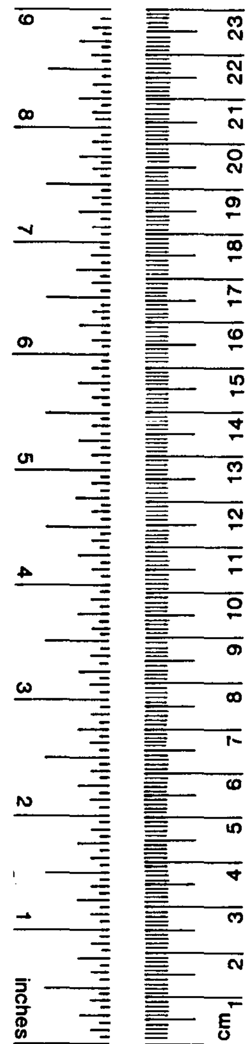
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

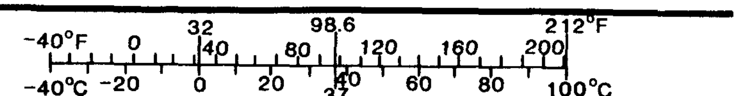
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly).



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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E.1 Introduction

The primary objective of this study is to provide Measures of Effectiveness (MOEs) of the U.S. Coast Guard Marine Inspection and Boarding Program based on objective scientific methods. A secondary objective of the study is to provide USCG management with a methodologically and theoretically sound aid to effective policy decision-making. Although the measures of effectiveness constructed in this study are specific to the Marine Inspection and Boarding Program, the methodology of the study is based on sound theoretical principles that are probably applicable to a range of USCG activities. Hence the methodology applies equally to other important USCG programs and can be similarly used to measure their effectiveness and as an aid to decision-making.

Measures of effectiveness are provided at three levels: an overall, Program-wide level (Level I), a major activity level (Level II), and a more disaggregated sub-activity level (Level III). Level II activities cover major activities including Certificate of Inspections (COI), Reinspections, Hull Drydock Exams, and Foreign Flag Annual Vessel Examinations. Level III MOEs cover the principal components that make up a vessel inspection or boarding including sub-activities related to Cargo Handling, Pollution Control, Steering and Navigation, Document, Drills, Auxiliary Equipment Power Plant, Fire-Fighting, Hull, and Life Saving. Data pertaining to deep-draft vessel inspections and boardings from the Marine Safety Management System (MSMS) database provide the inputs in the construction of the MOEs. The detailed analyses and results of this study are included in the Main Report - Volume II and the Appendices - Volume IV of this report.

Implementation of the results of the econometric analysis was done by using decision support system (DSS) technology. A DSS is an interactive, flexible and adaptable computer-based system that employs a model(s) to aid in problem solving and decision making. A key component of any DSS is the human-machine interface; it should allow the user to interact with the model(s) and display its results in an easy-to-understand format. The prototype DSS was developed for the USCG Office of Marine Safety on a PC workstation allowing graphical displays and interaction with the model(s) via a "spreadsheet" format, in Excel. The prototype DSS is presented in greater detail in a companion document, "Decision Support for Utilizing Measures of Effectiveness-Volume III." In addition, a description is provided of how the measures of effectiveness could be integrated with a resource allocation methodology to support USCG Office of Marine Safety staff in budgeting, organizational redesign and other management activities.

E.2 Methodology

Two separate approaches, which complement each other nicely, are employed in this study. The first approach employs state-of-the-art econometric models in the analysis of a behavioral relationship between the *number of Personnel and Pollution casualties* and *resources expended* by the Marine Inspection and Boarding Program. The ensuing estimates directly provide measures of effectiveness of the Program by (i) quantifying the *decrease* in the expected number of Personnel casualties (deaths,

missing, injured) and Pollution casualties that result from an increase in the expenditure of such resource hours, and (ii) quantifying the *increase* in the expected duration-to-casualty resulting from an increase in resources. Graphical analysis to ensure integrity, and extensive sensitivity analyses to test for robustness of the econometric results are performed. The econometric models are employed to provide measures of effectiveness at the Program, Major activity, and Sub-activity levels. Measures of effectiveness from the econometric approach are broken down by (i) type of service, and (ii) type of flag. The second approach, called Risk-Based Ranking (RBR) [Wheeler (1993)], is used to enumerate the contribution of factors, which are targeted by Level III activities as being key contributors to the occurrence of casualties, to the risk of Personnel and Pollution casualties. The RBR constructs measures of importance for each Level III activity. Large importance measures underscore those activities that may be expected to offer the largest returns from concentrating resources in those areas. We provided risk-based rankings and importance measures broken down by (i) type of service, (ii) type of flag, and (iii) MSO and district. In addition to being stand-alone results, the risk-based rankings also critically supplement the results of the econometric analysis and provide valuable information in efficient decision-making based on the econometric results.

E.3 Inferences: Marine Inspection Program

Tables E.1 through E.6 summarize the significant results from the econometric models developed and displayed in the tables of the Main Report - Volume II. The independent variables are listed in the first column and dependent variables are listed in subsequent columns. If a dependent variable was found to be significant in at least one of the statistical models developed in the main report, then an "X" is indicated in the appropriate box. To illustrate the interpretation of these tables, consider Table E.1. For the independent variable "Hull Hours" for Passenger Vessels, there is an X in the columns under dependent variables "Personnel Casualties" and "Injuries". This indicates that Hull inspection hours on passenger vessels were significant in reducing personnel casualties and injuries for US Flag Vessels. For the duration models such as Tables E.2 through E.4, X's indicate that the independent variable is significant in increasing the time to occurrence of a casualty. These tables are a compilation of the results from many tables and should not be misinterpreted as the results from just one statistical model. The tables in this volume are to be used to get a general idea of the types of relationships that were found to be significant. For a more thorough understanding of the significance of these results, the specific table in the Main Report should be referenced. These tables will be referenced in parentheses for cross reference purposes throughout this volume.

From an analysis of 951 U.S. flag deep-draft vessels, the econometric estimates provide clear and strong evidence that the resources expended by the Marine Inspection Program are effective in reducing the expected number of deaths, injuries, and pollution incidents. At Level I, the results attest (table 4.4.1) to the effectiveness of each type of resource hour expended - hours devoted to hull activities (Hull hours) and hours devoted to machinery activities (Machinery hours) - in reducing deaths, the results provide evidence (table 4.4.2) of their effectiveness in reducing injuries especially on Freight ships and Tank ships, and strong results were obtained that attest to their effectiveness in

reducing pollution occurrences (table 4.5.2), especially on Tank ships. The statistical significance of the results is all the more stronger if in interpreting the estimates presented we recognize that the primary objective of USCG inspections is to prevent events of great significance, such as deaths, serious injuries, and large oil spills. In statistical terms, we consider *t*-statistics greater than 1.00 in absolute value to be statistically significant in assessing effectiveness of the Program. By this standard, Hull and Machinery hours are each highly effective (table 4.5.2) in reducing pollution occurrences on both Freight and Tank ships. Hull and Machinery hours were found to be highly effective in reducing personnel Deaths and Missing casualties (table 4.4.1), particularly in Passenger and Freight ships. From the estimates in these tables we can quantify the expected number of casualties that may be reduced by increasing resource hours. For example, the estimate of -1.167 for Hull hours in the model for Personnel Casualties on U.S. Flag vessels (table 4.4.1) implies that the expected number of Deaths and Missing can be reduced by .03[1] (over a 3-year period) if Hull hours are increased by 1000 (over a 5 year period). The corresponding numbers for injury reduction is .12 over a 3-year period (table 4.4.2), and for the reduction in pollution occurrences it is .29 over a 3-year period (table 4.5.2).

At Level II we use the Duration models to infer how a change in the deployment of resource hours affects the *time to a Personnel or Pollution casualty.* This model is employed because Level II activities are naturally defined in terms of duration. For example, a Freight ship COI is required once every two years, Reinspections (Activity II.A.2) are required in alternate years, Hull Exams (Activity II.A.3) are required twice every five years with the requirement that not more that 3 years elapse between two inspections, and Annual Exams (Activity II.B.1-3) are required of Foreign flag vessels every year. Hence the effectiveness of these activities is best measured in how much longer they are able to prolong casualty-free operation of a vessel. Results from the duration analysis given that a Certificate of Inspection was performed, shows Machinery hours and Administrative hours to be strongly effective in *increasing* time to Personnel casualty, particularly in Freight ships (tables 4.6.3 and 4.7.3). If a 70% significance level is used (t=1.00) then each resource variable is effective in increasing time to Personnel casualty on vessels of almost all services. COI's are, however, not shown to be as clearly effective in prolonging Pollution casualties as they are for Personnel casualties, and only very weak inferences can be drawn on this count. Reinspections are clearly shown to prolong duration to Personnel casualties for all services (table 4.8.3), but the Pollution results (table 4.9.3) do not allow any inferences about the effectiveness of Reinspections in reducing pollution casualties aboard Freight ships and Tank ships. The results for Hull Exams (tables 4.10.3 and 4.11.3) are strong and impressive. Hull hours are effective in increasing time to Personnel casualties in vessels of all services, while Machinery hours are effective for Freight ships. Hull hours are particularly effective in reducing Pollution casualties on Freight ships and Passenger ships. Clearly Hull Exams successfully achieve their safety goals in increasing time to Personnel as well as Pollution casualties.

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[1] Using the formula for model #1 in table 4.4.1 of the main report, EXP(-4.573-1.167(1)-.007(25))= .03

At Level III the results are impressive and strongly attest to the effectiveness of each Level III activity in reducing Personnel and Pollution casualties. A Poisson model of casualties, similar to those employed in assessing Level I effectiveness of Marine inspection of U.S. deep-draft vessels is employed here. Hours devoted to Cargo Handling/Pollution Control were found to be effective in controlling pollution occurrences (table 4.12.3). Results for other Level III activities (Tables 4.13.1 through 4.14.3) indicate a great degree of success in controlling pollution and personnel casualties.

E.4 Inferences: Foreign Vessel Boarding Program

The results from an analysis of 10,904 Foreign flag deep-draft vessels are not as strong and unambiguous as those for U.S. flag deep-draft vessels. The number of Foreign flag deep-draft vessels examined by the USCG far outnumbers the number of U.S. flag deep-draft vessels. But whereas U.S. flag vessels are subject to inspection requirements laid down by he USCG, and hence are subject to thorough safety checks, this is not always true of Foreign flag vessels. The desired outcome of USCG inspections with respect to Foreign flag vessels is to minimize Personnel and Pollution casualties *in U.S. waters*, whereas the objective with regard to U.S. flag vessels is to minimize casualties *anywhere*. Does the USCG Boarding Program successfully achieve this objective? If so, is there evidence that the USCG achieves this efficiently? The first question can be answered unconditionally, simply by observing the number of Personnel and Pollution casualties that have occurred since 1991. Between 1991 and 1993 there were 61 Deaths and Missing, 97 Injured, and 535 Pollution occurrences. Since well over 10,000 deep-draft vessels were examined over these years the casualty rate is impressively low. Clearly, the USCG program of examining Foreign flag vessels is successful in achieving very low numbers of incidents with grave consequences such as deaths and missing and large pollution casualties in U.S. waters. The answer to the second question is not easy to obtain for two reasons. Compared to U.S. flag vessels, there is much more uncertainty about the state (i.e., condition) of a Foreign flag deep-draft vessel that enters U.S. waters than is the case for a U.S. flag deep-draft vessel. Foreign flag vessels are subject to widely varying degrees of monitoring and regulation depending on their flag, which can just as easily change from one port call to another. This makes the distribution of USCG resource hours in examining/monitoring a more complicated and fuzzy task than it is in the case of U.S flag vessels. We believe a complete analysis of the Foreign flag examination program must involve a deep examination of the nature of the monitoring/boarding problem. We feel that it may be possible to design a "contract" with Foreign flag vessels which enables the USCG to obtain better information about the state of the vessel on a "voluntary" basis. This is akin to insurance companies designing contracts in a manner that allows them to "voluntarily" obtain information about potential insureds. We feel that it is possible to design such an optimal contract that provides the proper incentives to Foreign flag vessels. According to the present system, the only incentive a foreign flag shipowner has to comply with USCG safety standards is a nominal monetary penalty. Hence the onus is entirely on the USCG to detect and correct problems on Foreign flag vessels. Naturally the use of USCG resources will not be as efficient as in the case where the Foreign flag shipowner "volunteers" correct information. The motivation for the study of optimal incentive contracts is two-fold. Firstly, the provision of better information pertaining to a Foreign flag vessel can significantly lower the resource expenditure on such vessels, which can lead to substantial savings given the large amount of resource hours spent by the USCG on Foreign flag exams and boardings. Secondly, since better information allows a narrower focus, USCG resources

can be deployed more efficiently.

At Level I, It is shown that hours spent by active duty personnel (Regular Hours) and hours spent by reserve personnel (Reserve Hours) aboard Freight ships are effective in reducing Deaths and Missing (table 4.15.1), but these hours are not effective in controlling injuries. For Passenger vessels, Regular hours are found to be effective in controlling injuries (table 4.15.2). For Tank ships, Regular hours were found to reduce injuries (table 4.15.3). Results indicate that Regular hours are clearly effective in reducing Pollution casualties in vessels of all services, particularly Freight and Tank ships (table 4.15.4). Various other model specifications were estimated, and if estimates on resource hours are compared across the range of specifications, we arrive at the conclusion that these estimates are not robust to changes in model specification. Certainly the Foreign flag estimates are much more sensitive than the corresponding U.S. flag results and do not allow strong and unambiguous inferences.

At Level II, the results for Personnel casualties are again sensitive to specification changes. The duration analysis of Pollution casualties leads us to the conclusion that there is some evidence, although weak, that Regular hours devoted to Annual Examination of Tank ships is effective in prolonging time to casualty (table 4.17.1). But the same results based on specifications where the resource hours are scaled by gross tonnage of the vessel, show that Annual Tank ship Examinations are ineffective in prolonging the duration to a pollution casualty (table 4.17.3), while no clear inferences may be drawn about Annual Freight ship Examination (table 4.17.2).

E.5 Risk-Based Ranking results

From an analysis of Freight, Passenger, and Tanker vessel casualty and inspection data logged in the Marine Investigations Module (MINMOD) of the MSMS database, dominant contributors to maritime risk were identified. Using MSMS casualty data between 1991 and 1993, the risk-based rankings analysis shows that MSMS MINMOD data do attribute most risks associated with Freight, Passenger, and Tanker vessel operations to casualty causes that fall under the purview of the USCG's Level III intervention strategies. The analysis indicates that most risk is attributed to causes that are linked to the Drills/Human Factors, Steering/Navigation, and Cargo/Pollution Control Level III intervention strategies, and to a much lesser degree, the Power Plant and Fire Suppression and Prevention strategies. The "importance" of risk that could not be attributed to any of the Level III activities tended to be less than 10% of the risk associated with the most dominant Level III strategies. The results for the highest level of data aggregation (USCG wide) are summarized in Tables E.7 through E.12. Table E.9 can be used as an example to interpret these tables. Looking at the first row of data for Freight vessels, the 1.00 listed under the "Drills/Human Factors" Level III intervention strategy indicates that the risk for the consequence of "Death" is most dominated by Drills/Human Factors related causes. Steering/Navigation related causes are the next most dominant factor and are 50% as important as Drills/Human Factors, followed by Cargo/Pollution related causes which are 29% as important as Drills/Human Factors, and so on. The general trend for U.S. Freight and Tanker vessels is the following: the most dominant risk contributor is Drills/Human Factors, followed by Steering/Navigation (which tends to be only half as important), and then Cargo/Pollution Control (approximately a third as important). For U.S. Passenger vessels results are similar except

that the rankings of Drills/Human Factors and Steering/Navigation are reversed. For Foreign flag Freight and Tanker vessels the dominant risk contributor is Cargo/Pollution Control, followed by Steering/Navigation (which is almost equal in importance), and then Drills/Human Factors (which tends to be approximately only 15% as important). For Foreign flag Passenger vessels the results have Drills/Human Factors as the most dominant contributor followed by Steering/Navigation (approximately 15% as important), and no other contributors were shown to be more that 5% as important as Drills/Human Factors. Similar results can be inferred for the District level analysis.

E.6 Risk-Based Ranking and Econometric Modelling as Aids to Decision-Making

E.6.1 Methodology

The risk-based ranking methodology nicely complements econometric modelling when they are used as decision tools. The econometric estimates provide an answer to the following question: "If we increase USCG resource hours by *x%*, how much will that buy in reduced personnel and pollution casualties?" By itself, and without making further assumptions, however, the econometric estimates will not inform USCG policy-makers how to divide a fixed pie of resources among various activities efficiently. This is especially true if, as in the case of U.S. flag deep-draft vessels, *many* activities are shown to be effective in reducing personnel and pollution casualties. In order to target those activities that will give the largest returns to an increase in resource hours, decision-makers can look to risk-based ranking measures of importance to indicate areas that are large contributors to risk.

E.6.2 Implementing Results

Consider the econometric results pertaining to U.S. flag Level III activities. The results from nearly all the statisical models attest to the fact that an increase in resource hours will lead to substantial decrease in casualties. However, in order to obtain reductions in deaths, injuries and pollution casualties, many thousand hours of resources must be devoted to these activities, and given a constraint on the number of resource hours available to the USCG, decision-makers are faced with the difficult question of how to apportion hours efficiently among activities. The importance measures from the risk-based rankings provide a natural answer. The largest increase in hours should be devoted to those activities that cover factors contributing to the greatest risk of casualties. For example, from Tables E.9 and E.11, increases in resource hours are most effective if devoted to Drills/Human Factors and Steering/Navigation on Freight ships, to Steering/Navigation and Drills /Human Factors for Passenger ships, and to Drills/Human Factors, Steering/Navigation, and Cargo Handling/Pollution Control for Tank ships. We emphasize that the risk-based ranking importance measures inform only about *contribution* of factors to risk, and we should not make strong inferences about risk *reduction* or risk *increase*. For example, just because activities other than those listed above have importance measures close to zero does not mean that removing resources from these activities will do no harm. These activities may have low importance values precisely because USCG inspections are effective in eliminating the contribution to the risk of casualties by factors covered by these activities. We need to look to the econometric estimates to provide answers about risk reduction. While so doing, the following caveats need to be observed. Firstly, the econometric estimates should not be extrapolated beyond the range of data used for the sample. Hence if the sample does not contain an observation (vessel) with zero resource hours devoted to it, we cannot

ask of the econometric results to provide an answer to the question of what would happen to personnel and pollution casualties if USCG inspections and boardings came to a complete halt. Econometric estimates are most reliable for counterfactual experiments that consider small variations of resource hours around their sample means. Secondly, econometric results are not substitutes for personal judgment and expert opinions possessed by USCG personnel with substantial field experience. Rather, they are meant to complement such judgments. Where the econometric and risk-based ranking measures corroborate experience and personal judgement, the foundation for decision-making is that much stronger. Where the data-based measures conflict with personal judgment, either personal judgments must be revised, or new data must be brought to bear on the problem, or both. These recommendations are deep-rooted in the decision-theoretic literature.

E.7 The Prototype Decision Support System

A prototype DSS was developed to aid USCG program management in using the econometric models that generate measures of effectiveness for the Marine Inspection and Boarding Program. An easy to use, flexible spreadsheet format was employed for the human-machine interface. Representative models were programmed in Excel, the spreadsheet software selected for the prototype DSS, and various displays constructed. The interface with displays was assessed by USCG program management. Rapid prototyping was used as the development process. Extensions to the prototype were suggested to incorporate measures of effectiveness into the resource allocation decision making by USCG program management. As part of the rapid prototyping process, various displays were created, implemented in Excel and presented to the USCG for review. The focus of the effort was on models for determining effectiveness as is described in a tutorial companion volume entitled, "Decision Support for Utilizing Measures of Effectiveness - Volume III." In this DSS tutorial, models from the econometric MOE analysis are presented. An example of the output from a Poisson model of pollution casualties for U.S. Flag vessels is displayed in Figure E.1 which graphically depicts the inverse relationship between resourse hours and pollution occurrences.

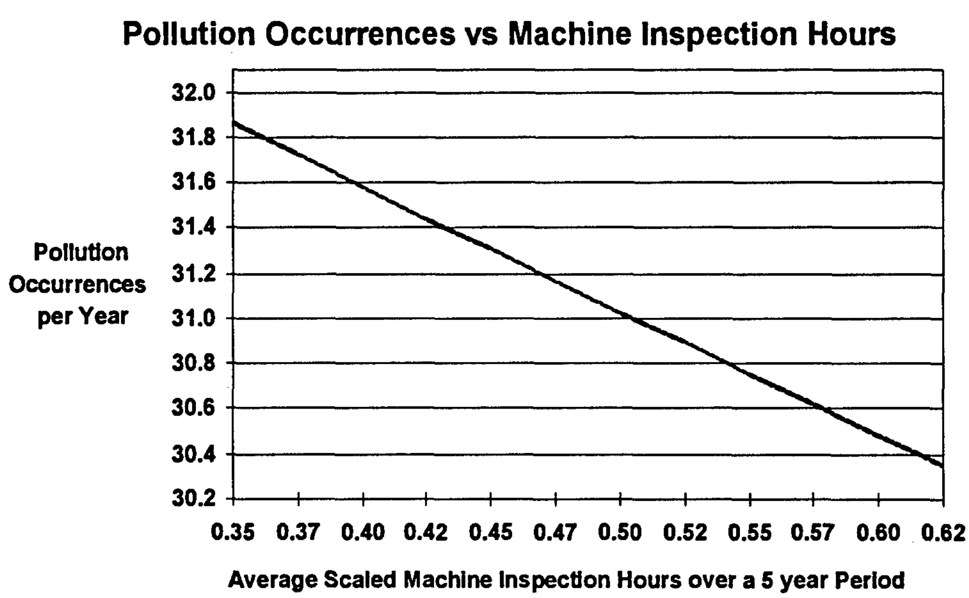

Figure E.1 DSS Model Display, Pollution Occurences vs. Machine Inspection Hours

E.8 Recommendations for Further Analysis

1. Our recommendations for further analysis of the effectiveness of USCG activities on Foreign flag vessels has to do with the quality and completeness of the data. As it stands, the data provides information on only "half" the experiment. There is neither data on the monitoring effort on Foreign flag vessels that occurs outside U.S. waters, nor is there data on the occurrence of casualties outside U.S. waters. We are thus inferring the effectiveness of USCG activities based on a truncated information set, and clearly the inferences will be much weaker than those based on the complete information set. A fruitful line of enquiry concerns the possibility of merging the MSMS database with Lloyds' databases.

2. We strongly recommend undertaking a study that analyzes the incentive problems innate to the examination of Foreign flag vessels and designs an incentive mechanism that somewhat relieves the USCG of the burden of extracting *all* (hidden) information about the state of the vessel by ensuring that vessel operators "voluntarily" provide some information. This would enable economically better and more efficient decision-making about the Boarding Program, especially since a large proportion of USCG resources are devoted to it.

3. The mapping from inspection types in the Case Resourse Supplement Table (CRST) of the MSMS database into Level III activities should be a more sophisticated *fractional* mapping which gives information about the fraction of hours from a CRST inspection type that goes into each Level III activity. It may be possible to amend the CRST inspection types so that such a fractional mapping becomes more sensible. Then the Level III analysis of Foreign flag vessel examinations also becomes possible.

4. The process of developing rankings of inspection/boarding strategies important to safety depends significantly on the quality of data that identifies causal information and links it back to intervention strategies. The level of detailed causal data in MSMS MINMOD is somewhat limited, and represents a significant restructuring of causal data in the transition from the old CASMAIN casualty database (more comprehensive in this regard) to the new MINMOD casualty database (less comprehensive). Our recommendation in this regard is therefore that casualty causal data should be redefined in order to be informative about Level III activities.

5. The prototype DSS should be fully implemented by incorporating additional models into the spreadsheet format in Excel. As described in the companion volume, three models were implemented for demonstration and assessment purposes. USCG staff should prioritize the model described in this report and implement as time and resources permit.

6. A "model management" interface should be developed. This interface would guide the user to the model most appropriate to the management task being addressed by USCG program staff.

Table E.1 Significant Results Summarized from US Flag Vessels Tables 4.1.1 - 4.5.2 in the Main Report

	Dependent Variables			
Independent Variable	**Personnel Casualties**	**Deaths and Missing**	**Injuries**	**Pollution Incidents**
Overall Hours				
Gross Tonnage	X	X	X	X
Age	X	X	X	
Hull Hours	X	X	X	X
Machine Hours	X		X	X
Passenger Vessels				
Hull Hours	X		X	
Machine Hours	X		X	
Freight Vessels				
Hull Hours	X	X	X	X
Machine Hours	X	X	X	X
Tank Vessels				
Hull Hours	X	X		X
Machine Hours	X	X	X	X

Table E.2 Significant Results Summarized from US FlagVessel Duration Models for COI's Tables 4.6.1 - 4.7.3 in the Main Report

	Dependent Variables	
Independent Variable	**Personnel Casualties**	**Pollution Incidents**
Overall Hours		
Gross Tonnage	X	X
Age	X	X
Hull Hours	X	
Machine Hours	X	
Passenger Vessels		
Hull Hours	X	
Machine Hours		X
Freight Vessels		
Hull Hours	X	X
Machine Hours	X	
Tank Vessels		
Hull Hours		
Machine Hours	X	X

Table E.3 Significant Results Summarized from US Flag Vessel Duration Models for Reinspections
Tables 4.8.1 - 4.9.3 in the Main Report

	Dependent Variables	
Independent Variable	**Personnel Casualties**	**Pollution Incidents**
Overall Hours		
Gross Tonnage	X	X
Age	X	X
Hull Hours	X	
Machine Hours	X	
Passenger Vessels		
Hull Hours	X	X
Machine Hours	X	X
Freight Vessels		
Hull Hours	X	X
Machine Hours	X	
Tank Vessels		
Hull Hours	X	
Machine Hours	X	

Table E.4 Significant Results Summarized from US Flag Vessel Duration Models for Hull Exams
Tables 4.10.1 - 4.11.3 in the Main Report

	Dependent Variables	
Independent Variable	**Personnel Casualties**	**Pollution Incidents**
Overall Hours		
Gross Tonnage	X	X
Age	X	
Hull Hours	X	X
Machine Hours	X	X
Passenger Vessels		
Hull Hours	X	
Machine Hours	X	X
Freight Vessels		
Hull Hours	X	X
Machine Hours	X	X
Tank Vessels		
Hull Hours	X	
Machine Hours	X	X

Table E.5 Significant Results Summarized from US Flag Vessels Poisson Models for Level III activities

Independent Variable	Dependent Variables: Injuries	Pollution Incidents	Deaths and Missing
Age	X		
Activity III.1 Cargo/Pollution Handling/Pollution Control (Tables 4.12.1 - 4.12.3)			
Overall Hours			
Hull Hours	X	X	X
Machine Hours	X	X	X
Passenger Vessels			
Hull Hours			
Machine Hours		X	X
Freight Vessels			
Hull Hours	X	X	
Machine Hours	X	X	
Tank Vessels			
Hull Hours	X	X	
Machine Hours	X	X	
Activity III.2-7 Steering and Navigation - Fire Fighting and Prevention			
Overall Hours			
Hull Hours	X	X	X
Machine Hours	X	X	X
Passenger Vessels			
Hull Passenger		X	
Machine Passenger		X	X
Freight Vessels			
Hull Freight	X	X	
Machine Freight	X	X	
Tank Vessels			
Hull Tank	X	X	
Machine Tank	X	X	
Activity III.8 Hull Inspections (Tables 4.14.1 - 4.14.3)			
Overall Hours			
Hull Hours	X	X	X
Machine Hours	X	X	X
Passenger Vessels			
Hull Passenger		X	
Machine Passenger	X		X
Freight Vessels			
Hull Freight	X		
Machine Freight	X		
Tank Vessels			
Hull Tank	X	X	
Machine Tank	X	X	

Table E.6 Significant Results Summarized from Foreign Flag Vessels
Tables 4.15.1 - 4.17.4 in the Main Report

Independent Variables	Dependent Variables				
	Injuries	Pollution Incidents	Duration to Personnel Casualty	Duratio n to Pollutio n Casualty	Deaths & Missing
Overall Hours					
Gross Tonnage	X				X
Age	X				
Regular Personnel Hours	X				
Reserve Personnel Hours					X
Passenger Vessels					
Age Passenger					
Gross Tonnage		X			
Regular Personnel Hours		X			
Reserve Personnel Hours					
Freight Vessels					
Age Freight				X	
Gross Tonnage		X	X		
Regular Personnel Hours		X	X	X	
Reserve Personnel Hours			X	X	
Tank Vessels					
Age Tank				X	
Gross Tonnage		X	X		
Regular Personnel Hours		X	X	X	
Reserve Personnel Hours			X		

Table E.7 Risk-Based Ranking Bin Data Summary - USCG Wide Aggregation, U.S. Flag

Service	Inspections	Casualties	Relative Frequency	Casualty Frequency	Casualty Frequency Standard Deviation	Consequences			
						Deaths	Injuries	Property Losses	Pollution Releases (gal.)
FREIGHTER	1924	985	0.5072	0.51195	0.0114	11	324	$27,708,561	47,676
PASSENGER	4685	337	0.1735	0.07193	0.0038	2	50	$2,863,371	1259
TANKER	1204	620	0.3193	0.51495	0.0144	4	167	$6,554,482	8599
Total	7813	1942	1.0	-	-	17	541	$37,126,414	57,534

Table E.8 Risk-Based Ranking Bin Data Summary - USCG Wide Aggregation, Foreign Flag

Service	Boardings	Casualties	Relative Frequency	Casualty Frequency	Casualty Frequency Standard Deviation	Consequences			
						Deaths	Injuries	Property Losses	Pollution Releases (gal.)
FREIGHTER	17,916	870	0.67	0.05	0.0016	9	23	$23,959,892	440,208
PASSENGER	99	62	0.05	0.63	0.049	1	28	$13,020,000	300
TANKER	2557	363	0.28	0.14	0.0069	3	15	$2,679,945	161,471
Total	20,572	1295	1.0	-	-	13	66	$39,659,837	601,979

Table E.9 Risk-Based Ranking - USCG Wide Aggregation, US Flag, Relative Frequency Weighting

Service	Consequence	Level III Intervention Strategies									
		Cargo/ Poll.	Steering/ Nav.	Documents/ Paperwork	Drills/ Human Factors	Auxiliary Sys.	Power Plant	Fire Prevention	Hull	Lifesaving	Other
Freight	Deaths	0.29	0.50	0.00	1.00	0.00	0.08	0.04	0.10	0.00	0.08
	Injuries	0.30	0.48	0.00	1.00	0.00	0.08	0.04	0.13	0.00	0.07
	Property	0.37	0.57	0.00	1.00	0.00	0.11	0.05	0.14	0.00	0.07
	Pollution	0.22	0.43	0.00	1.00	0.00	0.05	0.03	0.08	0.00	0.07
Passenger	Deaths	0.09	1.00	0.00	0.42	0.00	0.05	0.07	0.07	0.00	0.07
	Injuries	0.10	1.00	0.00	0.38	0.00	0.16	0.08	0.10	0.00	0.03
	Property	0.10	1.00	0.00	0.36	0.00	0.16	0.08	0.07	0.00	0.03
	Pollution	0.17	1.00	0.00	0.36	0.00	0.12	0.06	0.03	0.00	0.06
Tanker	Deaths	0.51	0.67	0.00	1.00	0.00	0.05	0.01	0.18	0.00	0.14
	Injuries	0.55	0.71	0.00	1.00	0.00	0.10	0.03	0.21	0.00	0.08
	Property	0.59	0.99	0.00	1.00	0.00	0.10	0.03	0.22	0.00	0.09
	Pollution	0.80	0.74	0.00	1.00	0.00	0.13	0.05	0.31	0.00	0.08

Table E.10 Risk-Based Ranking - USCG Wide Aggregation, Foreign Flag, Relative Frequency Weighting

Service	Consequence	Level III Intervention Strategies									
		Cargo/ Poll.	Steering/ Nav.	Documents/ Paperwork	Drills Human Factors	Auxiliary Sys.	Power Plant	Fire	Hull	Lifesaving	Other
Freight	Deaths	1.00	0.84	0.00	0.11	0.00	0.08	0.02	0.06	0.00	0.07
	Injuries	0.94	1.00	0.00	0.15	0.00	0.10	0.02	0.06	0.00	0.08
	Property	1.00	0.87	0.00	0.13	0.00	0.09	0.02	0.07	0.00	0.06
	Pollution	1.00	0.88	0.00	0.10	0.00	0.10	0.01	0.05	0.00	0.07
Passenger	Deaths	0.00	0.14	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
	Injuries	0.05	0.16	0.00	1.00	0.00	0.01	0.02	0.00	0.00	0.00
	Property	0.00	0.14	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pollution	1.00	0.29	0.00	0.46	0.00	0.14	0.29	0.00	0.00	0.00
Tanker	Deaths	1.00	0.76	0.00	0.14	0.00	0.05	0.06	0.04	0.00	0.06
	Injuries	1.00	0.92	0.00	0.18	0.00	0.04	0.11	0.08	0.00	0.08
	Property	1.00	0.91	0.00	0.17	0.00	0.05	0.12	0.07	0.00	0.08
	Pollution	1.00	0.68	0.00	0.11	0.00	0.07	0.04	0.03	0.00	0.03

Table E.11 Risk-Based Ranking - USCG Wide Aggregation, U.S. Flag, Casualty Frequency Weighting

Service	Level III Intervention Strategy									
	Cargo/ Poll.	Steering/ Nav.	Documents/ Paperwork	Drills/ Human Factors	Auxiliary Sys.	Power Plant	Fire Prevention	Hull	Lifesaving	Other
Freight	0.36	0.58	0.00	1.00	0.00	0.12	0.05	0.15	0.00	0.07
Passenger	0.14	1.00	0.00	0.29	0.00	0.15	0.07	0.10	0.00	0.04
Tanker	0.63	0.72	0.00	1.00	0.00	0.15	0.04	0.22	0.00	0.08

Table E.12 Risk-Based Ranking - USCG Wide Aggregation, Foreign Flag, Casualty Frequency Weighting

Service	Level III Intervention Strategies									
	Cargo/ Poll.	Steering/ Nav.	Documents/ Paperwork	Drills/ Human Factors	Auxiliary Sys.	Power Plant	Fire Prevention	Hull	Lifesaving	Other
Freight	1.00	0.89	0.00	0.13	0.00	0.08	0.03	0.08	0.00	0.06
Passenger	0.33	0.21	0.00	1.00	0.00	0.04	0.08	0.00	0.00	0.00
Tanker	1.00	0.71	0.00	0.13	0.00	0.04	0.06	0.04	0.00	0.05

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